International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 7, Issue 6, Dec 2017, 247-254

FINITE ELEMENT ANALYSIS OF MONO COMPOSITE LEAF SPRING OF VARYING THICKNESS AND VARYING WIDTH USED IN AUTOMOTIVES

S. JEBAROSE JULIYANA, J. UDAYA PRAKASH, PALLAVI PATURU & A. DIVYA SADHANA

Department of Mechanical Engineering, Veltech Dr. RR & Dr. SR University, Chennai, India

ABSTRACT

The purpose of the work is, to analyze Unidirectional Glass Fiber/Epoxy mono composite leaf spring, for replacing the steel leaf spring by fiberglass composite leaf spring in automotives, by decreasing the weight and increasing the strength. A mono composite leaf spring with varying thickness, varying width design was analyzed for static linear and modal analysis. The FEA results showing stresses, deflections and natural frequency were verified with previous experimental results.

KEYWORDS: Composites, FEA, Modal Analysis & ANSYS

Received: Oct 20, 2017; **Accepted:** Oct 27, 2017; **Published:** Nov 11, 2017; **Paper Id.:** IJMPERDDEC201727

Original Article

INTRODUCTION

The leaf spring is used in self propelled vehicles as a flexible beam. It is used to transmit driving and braking forces from the axle assembly to the frame. Alloy steels of high quality are used for making leaf springs and it is semi- elliptic in shape. Single leaf and multi leafs are the two types of leaf springs. The single leaf is also called mono leaf spring. It is named as mono leaf spring because its center is thick and two ends are tapered down. Mono Leaf springs are specifically used in lighter suspension systems.

Nowadays automotive manufacturers as well as part makers are giving more importance to reduce the weight of the components. The best possible solution for the problem is the replacement of steel by composites. More research work was done in this area in this decade. A fiber glass epoxy composite was constructed based on part resistance and fatigue resistance. A mono leaf spring of variable width and variable thickness of glass epoxy is taken for analysis and its results were compared with steel.

Many literatures are available for properties and design of composite structures as well as for experimental stress analysis but finite element 2D analysis of leaf spring is very scarce. National and international standards are described in experimental procedures. In the present scenario by focusing on material synthesis and processing technology light weight vehicles can be produced.

There are several research works on the application of Composite materials in automotives. Rajendran [1,2] investigated composite structures, for automotives and optimized the design of composite leaf springs. Very good effort has been taken for the application of leaf springs in automotive industries [3,4]. Vijayarangan [5] produced FRPs, which has same load carrying capacity and reduced the weight of the machine element. Multi leaf springs were replaced by mono leaf springs made from FRPs [6,7].

DESIGN OF COMPOSITE MONO LEAF SPRING

Based on the consideration of different loading conditions of automotives the different kinds of leaf springs are designed and developed. The elastic energy stored by a leaf spring increases with increase in maximum allowable stress and increases with decrease in the modulus of elasticity in the longitudinal direction. Literatures reveals that e-glass /epoxy has all the characteristics to store strain energy. The unidirectional lay-up is selected in the longitudinal direction of the spring. The spring gets weakened at the mechanical joints and there is a necessity to strengthen this. The mechanical properties of steel and e glass epoxy are shown in Tables 1 & 2 respectively.

Table 1: Properties of Steel

Parameter	Value
Tensile strength (N/mm^2)	1962
Yield strength (N/mm^2)	1470
Young's modulus *E* (N/mm^2)	$2.1x10^5$
Design stress (σb) (N/mm^2)	653
Total length (mm)	1190
The arc length between the axle seat and the front eye (mm)	595
Arc height at axle seat (mm)	120
Spring rate (N/mm)	32
Normal static loading (N)	3850
Available space for spring width (mm)	60 – 70
Spring weight (kg)	26

Table 2: Properties of E GLASS/EPOXY

Parameter	Value
Tensile modulus along X-direction (Ex), MPa	34000
Tensile modulus along Y-direction (Ey), MPa	6530
Tensile modulus along Z-direction (Ez), MPa	6530
Tensile strength of the material, MPa	900
Compressive strength of the material, MPa	450
Shear modulus along XY-direction (Gxy), MPa	2433
Shear modulus along YZ-direction (Gyz), MPa	1698
Shear modulus along ZX-direction (Gzx), MPa	2433
Poisson ratio along XY-direction (NUxy)	0.217
Poisson ratio along YZ-direction (NUyz)	0.366
Poisson ratio along ZX-direction (NUzx)	0.217
Mass density of the material, kg/mm3	$2.6x10^{-6}$
Flexural modulus of the material, MPa	40000
Flexural strength of the material, MPa	1200

FINITE ELEMENT ANALYSIS

Finite Element Analysis makes it possible, to evaluate a detailed and complex structure, in a computer, during the planning of the structure. The demonstration in the computer of the adequate strength of the structure and the possibility of improving the design during planning can justify the cost of this analysis work. FEA has also been known to increase the rating of structures that were significantly over designed and built many decades ago.

STATIC ANALYSIS

To design composite leaf spring, a stress analysis was performed using the finite element method - ANSYS

software. Modeling was done with eight-node 3D brick element (solid 45) used for this work. The FEA results for steel and mono composite leaf spring (Glass/Epoxy) were compared.

MODELING

The keypoints were created at the centre and at the ends for design. Key points were connected by lines and volume was created by selecting the lines.

MESHING

The leaf spring was applied with Volume Sweep meshing. The mesh grade was choosen as 3. The grade varies from 10 (course) to 1(fine).

LOADING & BOUNDARY CONDITIONS

A static load of 3980 N is applied for Steel and 4250 N is applied for Mono Composite material at the eye end for varying thickness, varying width design. The load is applied at the nodes of eye end towards downward direction. The boundary condition is applied at the centre of the spring. The All DOF is arrested at the centre of the spring.

SOLUTION

Varying Thickness and Varying Width

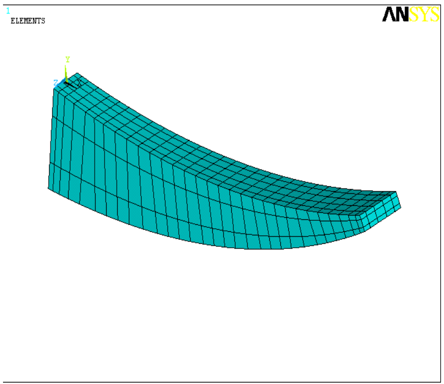


Figure.1: Element Plot - Mono Composite Leaf Spring

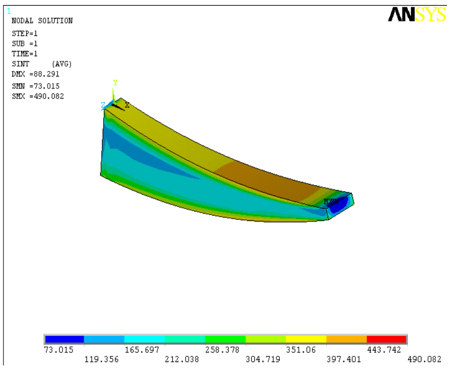


Figure2: Stress and Deflection Plot – Steel

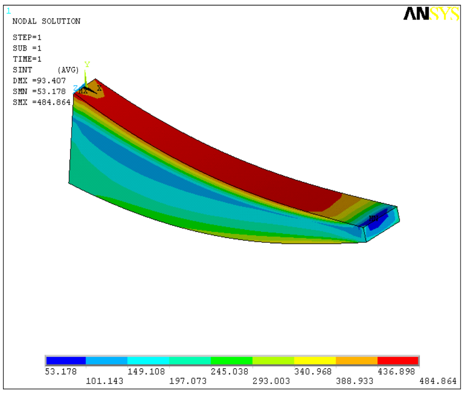


Figure3: Stress and Deflection Plot - Composite

Table 3: Results of Mono Composite Leaf Spring

Material	Static Load (N)	Maximum Deflection (mm)	Maximum stress (Mpa)	Weight (Kg)
Steel	3980	88.291	490.082	26.0
E-Glass/Epoxy	4250	93.407	484.864	3.88

MODAL ANALYSIS

The mode shapes of the structures and the natural frequencies are the most important parameters in dynamic loading conditions, and determined through modal analysis. The mode shapes of a cyclically symmetric structures are reviewed by modeling a sector of it through spectrum or mode superposition harmonic analysis or transient analysis.

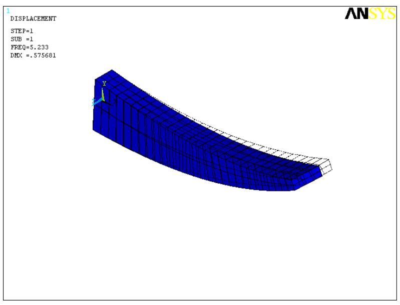
In ANSYS only linearity is considered in Modal Analysis. Mode extraction methods such as Block Lanczos, CG Lanczos, un symmetric, reduced, damped, and QR damped. The damped and QR damped methods helps in damping in the structure. The QR Damped method permits for unsymmetrical damping and stiffness matrices.

Modal Analysis is carried out for the following cases;

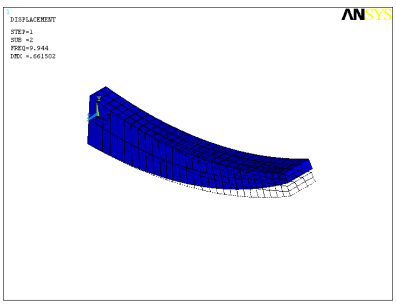
- Fixed at Centre and Free at End
- Free at Centre and Fixed at End

STEEL - FIXED AT CENTRE

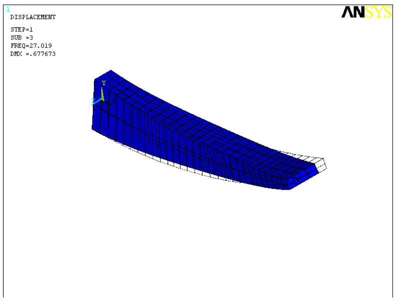
Mode	1	2	3	4	5
Frequency (Hz)	5.2332	9.9445	27.019	35.483	56.738



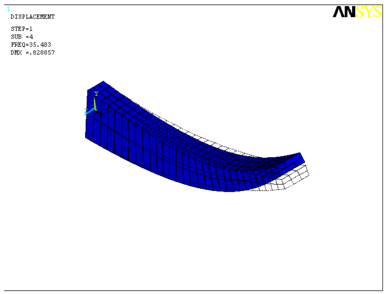
1st Modal Frequency



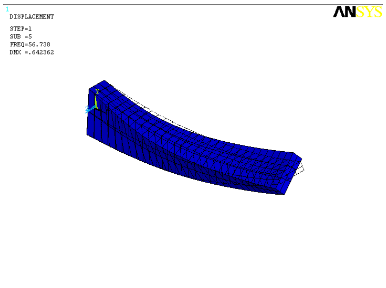
2nd Modal Frequency



3rd Modal Frequency



4th Modal Frequency

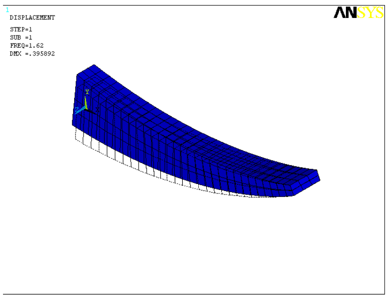


5th Modal Frequency

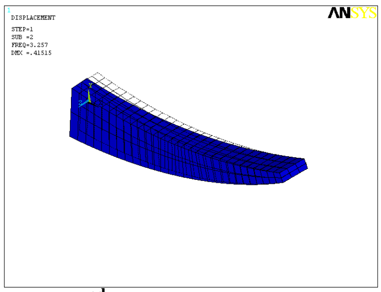
Figure.4: Modal Frequency Steel Fixed at Centre

STEEL - FIXED AT END

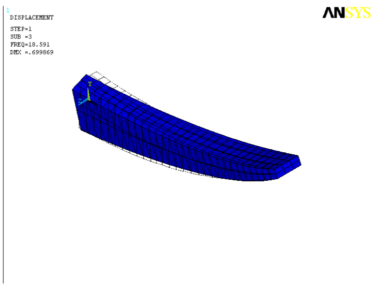
MODE	1	2	3	4	5
FREQUENCY (HZ)	1.6198	3.2571	18.591	19.895	26.568



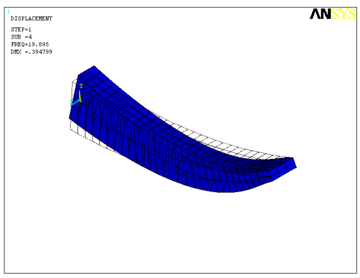
1st Modal Frequency



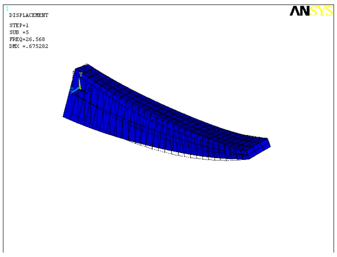
2nd Modal Frequency



3rd Modal Frequency



4th Modal Frequency

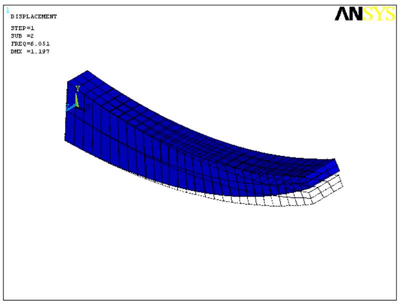


5th Modal Frequency

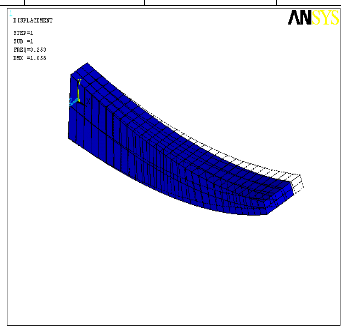
Figure 5: Modal Frequency Steel Fixed at End

COMPOSITE - FIXED AT CENTRE

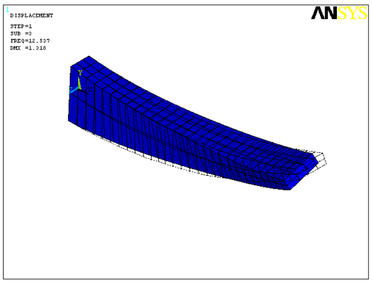
MODE	1	2	3	4	5
FREQUENCY (HZ)	3.2526	6.0508	12.537	17.561	22.581



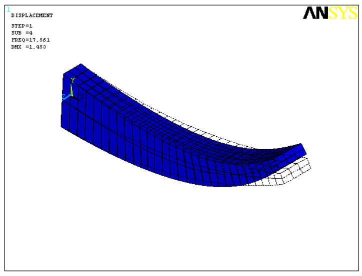
1st Modal Frequency



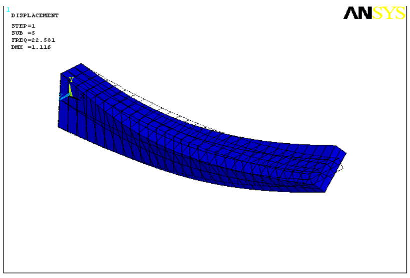
2nd Modal Frequency



3rd Modal Frequency



4th Modal Frequency

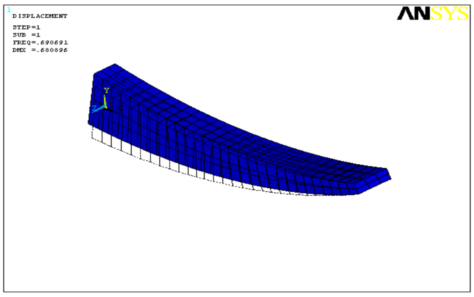


5th Modal Frequency

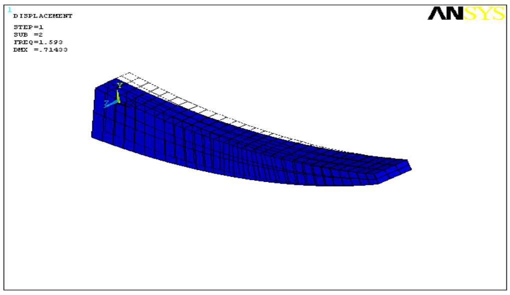
Figure.6: Modal Frequency Composite Fixed at Centre

COMPOSITE - FIXED AT END

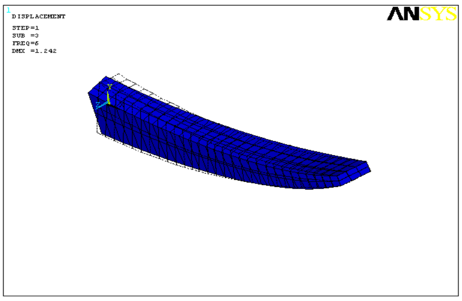
MODE	1	2	3	4	5
FREQUENCY (HZ)	0.69069	1.5933	6.0004	9.8817	11.976



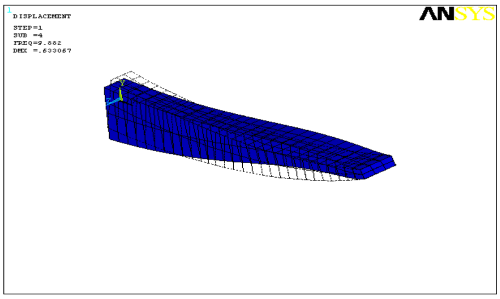
1st Modal Frequency



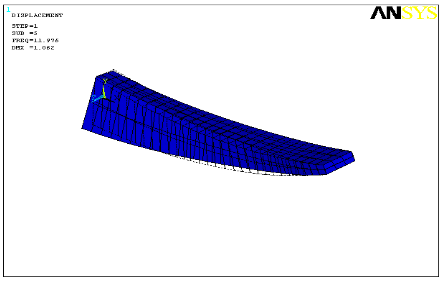
2nd Modal Frequency



3rd Modal Frequency



4th Modal Frequency



5th Modal Frequency

Figure.7: Modal Frequency Composite Fixed at End

The analysis results are tabulated and compared with experimental results.

Material	Static load (N)	Maximum deflection (mm)		MaximumStress (Mpa)		Weight (kg)
		FEA	Experiment	FEA	Experiment	
Steel	3980	88.291	107.5	490.082	503.3	26.0
E-Glass/Epoxy	4250	93.407	105.0	484.864	473.0	3.88

Modes		1	2	3	4	5
Steel – Fixed at centre	Frequency (HZ)	5.2332	9.9445	27.019	35.483	56.73
Steel – Fixed at end		1.6198	3.2571	18.591	19.895	26.56
E-Glass/Epoxy- Fixed at centre		3.2526	6.0508	12.537	17.561	22.58
E-Glass/Epoxy- Fixed at end		0.6906	1.5933	6.0004	9.8817	11.97

Hence, it is recommended that E-Glass/Epoxy can be used for leaf spring material.

CONCLUSIONS

From the results, it was identified that, the E-Glass/Epoxy has higher deflection and lower stress compared to steel. It is concluded that E-Glass/Epoxy has lower weight, higher deflection and lower stress.

Modal Analysis was also performed for mono leaf springs, for steel and E-Glass Epoxy for two boundary conditions. The boundary conditions are Fixed at centre and Fixed at end.

The results show that, E-Glass/Epoxy has lower frequency than steel. Hence, it is recommended that, E-Glass/Epoxy can be used for leaf spring material.

REFERENCES

1. **Rajendran, I., Vijayarangan, S.** *Optimal Design of a Composite Leaf Spring using Genetic Algorithms Int. Jr. of Computer and Structures 79 2001: pp. 1121 – 1129.*
2. **Rajendran, I., Vijayarangan, S.** *Design and Analysis of a Composite Leaf Spring Journal of Institute of Engineers India 82 2002: pp. 180 – 187.*
3. **Daugherty, R. L.** *Composite Leaf Springs in Heavy Truck Applications. K. Kawata,T.Akasaka (Eds). Composite Materials Proceedings of Japan-US Conference Tokyo, 1981: pp. 529 – 538.*
4. **Dharam, C. K.** *Composite Materials Design and Processes for Automotive Applications. The ASME Winter Annual Meeting, San Francisco, December 10-15, 1978: pp. 19 – 30.*
5. **Vijayarangan, S., Ganesan, N.** *Static Stress Analysis of a Composite Bevel Gear using a Three-dimensional Finite Element Method Computer Structures 51 (6) 1994: pp. 771 – 783.*
6. **Vandana Jain & Trapti Sharma,** *Analysis of Leaf Spring Conditions for Heavy Duty Vehicle, International Journal of Automobile Engineering Research and Development (IJAuERD), Volume 3, Issue 1, March 2013, pp. 97-104*
7. **S. D. Rathod, D. S. Shah & S. A. Ban,** *Comparative Study of Single Leave Leaf Spring in CAE Tool and Experimental Data of Leaf Springs in Automotive Vehicles, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Volume 3, Issue 3, August 2013, pp. 1- 8*
8. **Tanabe, K., Seino, T., Kajio, Y.** *Characteristics of Carbon/Glass Fiber Reinforced Plastic Leaf Spring, SAE 820403 1982: pp. 1628 – 1634.*
9. **Yu, W. J., Kim, H. C.** *Double Tapered FRP Beam for Automobile Suspension Leaf Spring Comp. Structure 1998: pp. 279 – 300.*
10. **Jones, R. M.** *Mechanics of Composite Materials. 2e, Mc Graw-Hill Book Company, 1990.*
11. **ANSYS Inc***: ANSYS Users Manual, Rev. 1995, 5.2-Vol. I – IV, Houston, PA.*